CHAPTER 2.4

Landfills and Combustion

Grade • Subject • Skills Index

Activity Name	Luscious Layered Landfill	A Landfill Is No Dump!	Energy Expedition	The Great Disposal Debate	Greenhouse Gases Be Gone
Grade Range					
K					
1	✔				
2	✔				
3	✔	✔			
4	✔	✔	✔	✔	
5		✔	✔	✔	
6		✔	✔	✔	✔
7				✔	✔
8				✔	✔
Subjects Covered					
Math					✔
Science	✔	✔	✔		✔
Language Arts			✔	✔	
Social Studies	✔	✔		✔	✔
Art					
Health					
Skills Used*					
Communication				✔	
Reading			✔	✔	✔
Research				✔	✔
Computation					✔
Observation/ Classification	✔	✔			✔
Problem Solving		✔	✔	✔	✔
Motor Skills	✔				

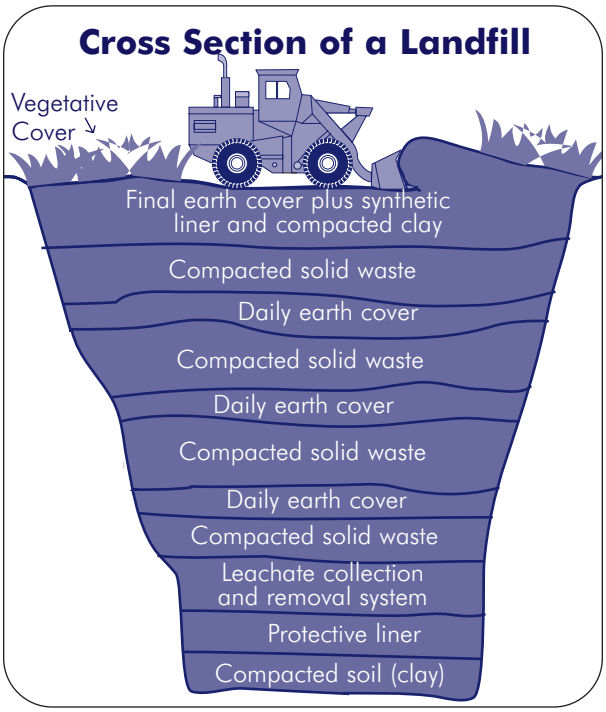
*See Glossary of Skills for more details.

Landfills

What Is a Landfill?

A landfill is a large area of land or an excavated site that is specifically designed and built to receive wastes. Today, about 56 percent of our country's trash is disposed of in landfills (EPA, 2003). Items such as appliances, newspapers, books, magazines, plastic containers, packaging, food scraps, yard trimmings, and other wastes from residential, commercial, and some industrial sources can be disposed of in **municipal solid waste landfills**. Municipal solid waste landfills can also accept some types of hazardous waste, such as cleaning products, paint, and chemicals, as well as some industrial wastes from certain businesses. Many states and communities, however, promote the safe collection of these hazardous wastes through local programs. (See "Are There Landfills for Hazardous Waste?" on page 166 for more information.)

In the past, garbage was collected in **open dumps**. These uncovered and unlined sites allowed **leachate**, a liquid formed by **decomposing** waste, to soak into the soil and **ground water**.



Key Points

- Landfills are the most common form of waste disposal and are an important component of an integrated waste management system.
- Federal landfill regulations have eliminated the open dumps of the past. Today's landfills must meet stringent design, operation, and closure requirements.
- Landfills that handle hazardous wastes are specially designed with two sets of liners and two leachate detection systems.
- After a landfill is capped, the land may be used for recreation sites such as parks, golf courses, and ski slopes.
- Methane gas, a byproduct of decomposing waste, can be collected and used as fuel to generate electricity.

Open dumps also attracted rodents and insects, emitted odors, and created fire hazards. Most of these small and unsanitary dumps have been replaced by large, modern facilities that are designed, operated, and monitored according to strict federal and state regulations. Today's landfills eliminate the harmful and undesirable characteristics of dumps to help protect public health and the environment.

In addition to being safer for the environment and neighboring communities, these larger landfills hold more trash than the dumps of the past. In 2001, about 1,850 municipal solid waste landfills were operating in the United States (EPA, 2003). While this number is significantly smaller than the number of landfills 25 years ago, new landfills—often called megafills due to their size—can accommodate significantly more garbage. This greater capacity is necessary to keep up with the steady growth of **municipal solid waste**.

Are There Landfills for Hazardous Waste?

In 2001, more than 1 million tons of hazardous waste was disposed of in landfills or surface impoundments. Hazardous waste is toxic, ignitable, corrosive, or reactive, or generated from certain industries or manufacturing processes. When it comes to disposing of hazardous waste in landfills, EPA takes additional steps to ensure environmental safety and human health.

While landfills that accept solid waste have a clay and plastic liner and a leachate system to prevent leakage, landfill owners that accept hazardous waste must take extra precautions. For example, a hazardous waste landfill must have two sets of liners, one consisting of a special plastic, and the other composed of both plastic and a thick layer of soil material. In addition, a landfill accepting hazardous waste must have two leachate detection systems instead of just one.

Before hazardous waste even reaches a landfill, however, it must be treated differently than solid waste. If hazardous waste is bound for disposal in a landfill, it is regulated under EPA's Land Disposal Restrictions program. Through this program, hazardous waste must undergo treatment that will destroy or immobilize its hazardous components before it is sent to a landfill. For example, when a business generates hazardous waste, it must either treat that waste itself, or send it to a special facility for treatment, before sending the waste to a landfill.

How Does a Landfill Work?

A typical modern landfill is lined with a layer of clay and protective plastic to prevent the waste and leachate from leaking into the ground or ground water. The lined unit is then divided into **disposal cells**. Only one cell is open at a time to receive waste. After a day's activity, the garbage is **compacted** and covered with a layer of soil to minimize odor, pests, and wind disturbances. A network of drains at the bottom of the landfill collects the leachate that flows through the decomposing waste. The leachate is sent to a **leachate recovery facility** to be treated. Methane gas, carbon dioxide, and other gases produced by the decomposing waste are monitored and collected to reduce their effects on air quality.

Landfills are regulated by federal and state laws. The federal laws dictate where landfills can be located, such as away from unstable land prone to earthquakes or flooding, and require them to be lined and have a **leachate collection system**. In addition, landfill owners must monitor and collect explosive gases; regularly test nearby ground water; and compact and cover waste with a layer of soil on a daily basis.

In addition to federal regulations, each state has its own landfill requirements, which are often more stringent than the federal laws. Many states require landfill operators to obtain a license and present a plan for how the site will be safely closed, even though the closing date might be 50 years in the future. Furthermore, federal law requires landfill owners to set aside the money to close the landfill properly and support ongoing monitoring activities. Once a landfill is capped (closed), the operator must monitor the site for gas and leachate for a minimum of 30 years after the closing date.

What Are the Benefits of Landfills?

In addition to providing a cost-effective, safe method to dispose of ever-increasing amounts of trash, landfills often provide other services to the community. For example, some landfills collect methane, a gas created by decomposing

Landfill Facts

- The first garbage dump was created in 500 BC by the ancient Greeks in Athens. Residents were required to take their trash at least 1 mile away from the city walls to dump.
- Paper takes up as much as 50 percent of all landfill space. Recycling 1 ton of newspapers would save 3 cubic feet of that space.
- In a study of waste buried for more than 15 years, Professor William Rathje of the University of Arizona found legible newspapers and chicken bones with meat still on them, proving that waste does not decompose completely in a landfill.

(Sources: The League of Women Voters' Garbage Primer, 1993; Rubbish! The Archaeology of Garbage by William Rathje, 1990; Anchorage Recycling Center, 2000)

garbage that can contribute to **global climate change**, and convert it into an energy source. In addition, after a landfill is capped and a certain amount of time has passed, the land might be reused for parks, ski slopes, golf courses, and other recreation areas.

What Are the Challenges of Landfills?

Though regulations have made landfills safer to the public and the environment, public opposition, high land prices, and environmental concerns can make it difficult to find suitable places for new landfills.

Landfills can pose other problems if not properly designed or managed. If a liner leaks, for example, the underlying soil and ground water can become contaminated. Additionally, since landfills are often located in remote areas, waste must be hauled long distances, which might result in environmental impacts from increased truck traffic (e.g., air pollution) and noise from truck traffic and the use of equipment onsite. Additionally, landfills often compete for local garbage within a given municipality. Competition can lead to reduced support for recycling and other waste reduction programs.

Issues also might arise if a landfill is located close to a community. Many people do not want landfills near their homes. The NIMBY (Not in My Backyard) attitude can make finding a landfill site very challenging.

What Are Some Emerging Trends?

Increased waste generation requires landfill operators and managers to constantly evaluate and improve current disposal methods. One strategy to speed the rate of decomposition of landfill waste is to recirculate the collected leachate by pouring it over the cells and allowing it to filter through the rotting garbage.

Another trend that is becoming common for landfill operators is collecting methane gas from the landfill and using it as the energy source to power the landfill or selling it to a local utility provider, company, or even greenhouses. This process allows landfills to reduce their dependence on precious **fossil fuels** and save money.

A new trend that is gaining attention is **landfill reclamation**, in which old cells are excavated to recover recyclable items. This process, in which recovered recyclables, soil, and waste can be sold, reused, or burned as fuel, is a new approach used to expand landfill capacity and avoid the cost of acquiring additional land.

Additional Information Resources:

Visit the following Web sites for more information on municipal solid waste landfills:

- U.S. Environmental Protection Agency (EPA): <www.epa.gov>
- U.S. EPA, Office of Solid Waste site on disposal: <www.epa.gov/epaoswer/non-hw/muncpl/disposal.htm>
- U.S. EPA Landfill Methane Outreach Program: <www.epa.gov/lmop>
- National Solid Waste Management Association: <www.nswma.org>
- Solid Waste Association of North America: <www.swana.org>

For more information on the disposal of hazardous waste in landfills, visit:

- U.S. EPA, Office of Solid Waste site on Land Disposal Restrictions: <www.epa.gov/epaoswer/hazwaste/ldr>
- U.S. EPA, Office of Solid Waste site on RCRA Hotline Training Modules (hazardous waste land disposal units): <www.epa.gov/epaoswer/hotline/modules.htm>

To order the following additional documents on municipal solid waste, call EPA toll-free at (800) 490-3198 (TDD 800 553-7672) or look on the EPA Web site <www.epa.gov/epaoswer/osw/publicat.htm>.

- *Sites for Our Solid Waste: A Guidebook for Public Involvement* (EPA530-SW-90-019).
- *Safer Disposal of Solid Waste: The Federal Regulations for Landfills* (EPA530-SW-91-092)
- *Decision-Makers' Guide to Solid Waste Management, Volume II* (EPA530-R-95-023)
- *A Collection of Solid Waste Resources* on CD-ROM

Combustion

What Is Combustion?

Recycling, composting, and source reduction are vital activities for effective solid waste management, but 100 percent of people's trash cannot be handled by these methods. The remaining waste must be deposited in landfills or combusted (burned). Because of limited space, landfills are not always a viable option in many cities, making ***combustors*** (commonly referred to as incinerators) an important part of a community's integrated waste management system. Burning garbage can decrease the volume of waste requiring disposal by 70 to 90 percent.

Before the late 1970s, many people burned garbage in their backyards and in simple private and municipal combustors. These methods did not burn garbage completely, however, and allowed pollutants to escape into the atmosphere. With the passing of the Clean Air Act, combustor owners had to develop more effective methods of pollution control. Today's municipal waste combustors release significantly less pollutants into the air than the "backyard burners" and simple combustors. More than 100 municipal waste combustor plants currently exist nationwide, and nearly 20 percent of the municipal solid waste generated in the United States is combusted.

Key Points

- Municipal waste combustors burn waste at high temperatures to reduce its volume.
- Municipal waste combustors reduce the volume of garbage by 70 to 90 percent.
- Ash is a byproduct of combustion that must be disposed of in landfills or reused.
- Air pollution control equipment helps reduce air emissions.
- The heat produced by burning waste in municipal waste combustors can be recovered as useful energy.
- Specially designed incinerators can be used as a means of handling hazardous waste. The burning process reduces the toxicity of organic compounds in the waste.

Facts about Municipal Waste Combustors

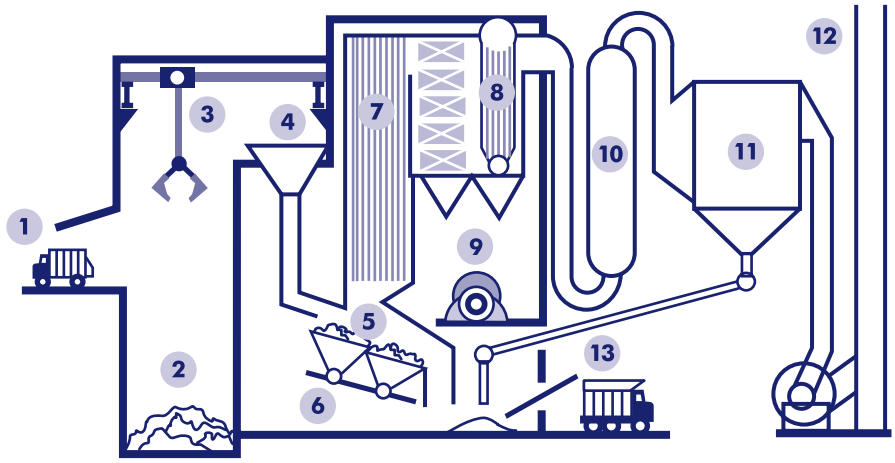
- Fire in the boiler of a combustor is often as hot as flowing lava (between 1,800 and 2,200 degrees Fahrenheit).
- In 1874, a new technology called "the destructor" provided the first combustor of municipal garbage in England.
- The first garbage incinerator in the United States was built on Governor's Island, New York, in 1885.

(Sources: Integrated Waste Services Association, 2000; Rubbish! The Archaeology of Garbage by William Rathje, 1990)

How Do Municipal Waste Combustors Work?

Municipal waste combustors dispose of trash by burning it at high temperatures. Not all municipal waste combustors are designed alike, but they function in a similar manner. Typically, a facility collects waste in a garbage receiving area or pit, where the garbage is mixed by a crane. The crane operator looks for large items that are not suitable for combustion

How Typical Combustion Facilities Work



1. Tipping area for trucks
2. Refuse pit
3. Refuse crane
4. Hopper, which sends waste to combustion zone
5. Primary combustion zone
6. Underfire air
7. Furnace
8. Heat exchanger
9. Turbine
10. Scrubber, to remove acid gases
11. Fly ash and dust collector
12. Stack
13. Bottom ash and fly ash collection and transport

Hazardous Waste Combustion

In addition to combustion facilities that accept municipal (nonhazardous) waste, specially designed incinerators, boilers, and industrial furnaces, can burn hazardous waste. Hazardous waste, which is toxic, ignitable, corrosive, or reactive, can be produced by businesses or manufacturing operations. Combustion has some key advantages as a means of managing hazardous waste. First, burning hazardous waste reduces the volume of waste by converting solids and liquids to ash. Second, the burning process destroys toxic organic compounds in waste. Third, disposal of the ash in a landfill is safer and more efficient than disposal of untreated hazardous waste. The ash generated from hazardous waste combustion must be tested and, if found to be hazardous, must be treated for remaining toxicity before it is disposed of in a landfill.

(e.g., batteries and refrigerators) and removes them from the pit. The crane operator also uses the crane to lift piles of garbage into a large chute. From the chute, garbage falls into a combustion chamber or furnace and then moves along a series of sloping grates that work like conveyer belts. The garbage is burned as it moves forward.

After garbage is burned, some matter remains in the form of ash. There are two types of ash: bottom ash and fly ash. Bottom ash is the heavier, nonburnable material, such as glass and metal, that falls through the grate after burning. Large pieces of metal accumulate in this ash and are extracted from the ash with magnets. Bottom ash accounts for about 75 to 90 percent of ash produced by incinerators. Fly ash includes lighter particles that rise with hot gases as the garbage is burned and are captured by air pollution control equipment in the stacks. All ash generated by combustion facilities must be tested to determine if it is hazardous. If it is hazardous, the ash is subject to special hazardous waste disposal regulations. If the ash is nonhazardous, it may

be deposited in landfills specially designed to store it. Currently, studies are under way to investigate ways to reuse ash; for example, to replace soil as a landfill cover (generally applied at the end of each day to minimize odor, pests, and wind disturbances). Ash might also be used in road and building construction and as part of artificial offshore reefs. Whether the leftover ash is recycled or landfilled, it takes up much less space than the same materials in their original form.

What Are the Benefits of Municipal Waste Combustors?

Most municipal waste incinerators in the United States generate energy in the form of electricity because certain materials, such as paper, plastics, wood, and packaging, make excellent fuels. Producing this energy has about the same environmental impact as energy produced from natural gas and less of an environmental impact than energy produced from oil or coal. In other words, generating energy from municipal waste combustors contributes no more pollution—and sometimes less—than processes generating electricity using natural gas, oil, or coal. Waste-to-energy plants also reduce the need to generate electricity from nonrenewable natural resources such as oil and coal.

What Are the Challenges of Municipal Waste Combustors?

Although technologies to control pollution have improved significantly, burning certain materials still produces chemicals that contribute to air pollution. To minimize emissions of air pollutants into the atmosphere, municipal waste incinerators use special equipment (e.g., scrubbers and dust collectors) to remove pollutants. To protect air quality and monitor the hazardous constituents in ash, EPA established regulations that apply to all large municipal solid waste units (those with the capacity to burn more than 250 tons of garbage per day). The regulations significantly reduce toxic air emissions such as dioxin, acid gas, lead, cadmium, and mercury.

Many people do not want incineration sites near their homes. The ***"NIMBY (Not In My Back Yard)"*** attitude makes finding appropriate sites for municipal waste combustors a challenge for many municipalities. There are, however, opportunities for the public to participate in deciding where a combustor will be located. Officials must hold a public meeting to inform the community about the size of the proposed combustor, as well as the amount of waste generation and ash to be discarded.

Additional Information Resources:

Visit the following Web sites for more information on municipal and hazardous waste combustion and solid waste:

- U.S. Environmental Protection Agency (EPA): <www.epa.gov>
- U.S. EPA, Office of Solid Waste site on disposal: <www.epa.gov/epaoswer/non-hw/muncpl/disposal.htm>
- Integrated Waste Services Association: <www.wte.org>
- Solid Waste Association of North America: <www.swana.org>

To order the following additional documents on combustion and solid waste, call EPA toll-free at (800) 490-9198 or look on the EPA Web site <www.epa.gov/epaoswer/osw/publicat.htm>.

- *Decision-Makers' Guide to Solid Waste Management, Volume II* (EPA530-R-95-023).
- *Sites for our Solid Waste: A Guidebook for Public Involvement* (EPA530-SW-90-019)
- *A Collection of Solid Waste Resources* on CD-ROM (EPA530-C-98-001)

science

social studies

Luscious Layered Landfill

Objective

To teach students how a modern landfill functions (that is, how its many layers contain garbage and prevent leakage into soil or ground water).

Activity Description

Students will construct edible models of a landfill to learn about its different layers and their functions.

Materials Needed

- One 8-ounce pliable clear plastic cup per student
- Five chocolate sandwich cookies per student
- One 8-ounce box of raisins
- One fruit rollup per student
- Two graham crackers per student
- Two red licorice sticks per student
- One package of birthday candles
- One set of matches
- One scoop of chocolate ice cream (or pudding) per student
- Two tablespoons of whipped cream per student
- One plastic knife per student
- One plastic fork per student
- One handful (per student) of a variety of small chewable candies (e.g, chocolate, peanut butter, fruit)
- One copy of *Anatomy of a Landfill* handout per student

Key Vocabulary Words

Landfill
Clay liner
Plastic liner
Leachate
Leachate collection pipes
Methane
Decompose
Rodent

Duration

1 hour

Skills Used

Observation/classification
Motor skills

Activity

Step 1: Refer to the Teacher Fact Sheet titled *Landfills* on page 165 for background information. Explain the purpose of a landfill to students and explain that they will construct their own model landfills in class. Copy and distribute the *Anatomy of a Landfill* handout. Using the handout, go over each layer's name and function with students.

Step 2: Distribute a cup and five chocolate sandwich cookies to each student. Explain that the cup represents an excavated hole in the ground.

Step 3: Have students carefully "unscrew" two of their cookies so that one half has white cream and the other is bare. Students should have two cookie halves with white cream and two cookie halves without cream. Crush the bare cookie halves into small pieces and put

Journal Activity

Ask students to list some common items that they throw away. What do they think people threw away 100 years ago? Ask them to predict what we will throw away in the future. What would they expect to find in a landfill in another country (pick a country)? Ask students to compare these answers with the United States.

them into the cup. Explain that the crushed cookies represent a layer of soil that is placed in the bottom of real landfills.

Step 4: Next, have the students take the cookie halves with white cream and break them up into two or three pieces. Direct students to place the pieces in the cup with the white cream face up. These pieces represent a layer of clay that is put on top of the soil in real landfills.

Step 5: Have students use the plastic knife to cut their fruit rollups to roughly fit the size of the top of cup and slide them into place (will push up on sides) on top of the cookies to represent a plastic liner. Plastic liners prevent leachate from escaping from a landfill into the ground. Leachate is liquid created when trash decomposes.

Step 6: Have students crush and add their graham crackers to represent a sand layer. This layer is used to prevent liquids in landfills from seeping out.

Step 7: Have students place raisins on top to represent a layer of pebbles. Like the sand layer, pebbles provide further protection against leachate leaks.

Step 8: Have students rip the licorice sticks in half and bite off both ends to represent leachate pipes. Stick pipes into pebble layer. These pipes collect any leachate that collects on top of the liners.

Step 9: Ask students to sprinkle the candies on top of the raisins. The candies represent pieces of garbage. Ask students to think about what happens when a landfill or "cup" is filled up with trash or "candies"? How can they reduce the amount of trash that they send to the landfill? (Refer to the Teacher Fact Sheet titled *Recycling* on page 101 for background information.)

Step 10: Give each student a scoop of ice cream on top of the candies. Then, have the students add one more layer of candies on top of the ice cream. The ice cream layer represents the seepage created from rain seeping through the garbage. Explain that in a real landfill, more layers of garbage or "candies" are placed on the landfill each day, so that liquid from the decomposition of the trash is continually created.

Step 11: Direct students to "unscrew" their two remaining cookies and crush another layer of the bare cookie halves, without the cream, on top of the candies and ice cream to represent soil again. (Students can eat the other cream-covered cookie halves.) This layer reduces the amount of rain water that reaches the garbage.

Step 12: Each student should use a layer of whipped cream to "cap" the landfill or cover it (as would a plastic cap) in order to prevent odor, insect, and rodent problems.

Step 13: In front of the class, stick a candle deep into your own edible "landfill" and light it. Explain that the candle represents the methane gas recovery system, which draws methane gas from the decomposing garbage. The flame represents energy that can be generated by burning the captured methane gas.

Step 14: Have students eat their landfills as a snack. When they get to the bottom of their cup, ask students to notice whether their cookie or "soil" layer is dry, or whether the ice cream or "leachate" leaked past the many layers and the fruit roll-up liner to soak the cookies. Remind students that if they built their landfill correctly, their cookies will be dry, just as in a real landfill the soil remains protected from leachate.

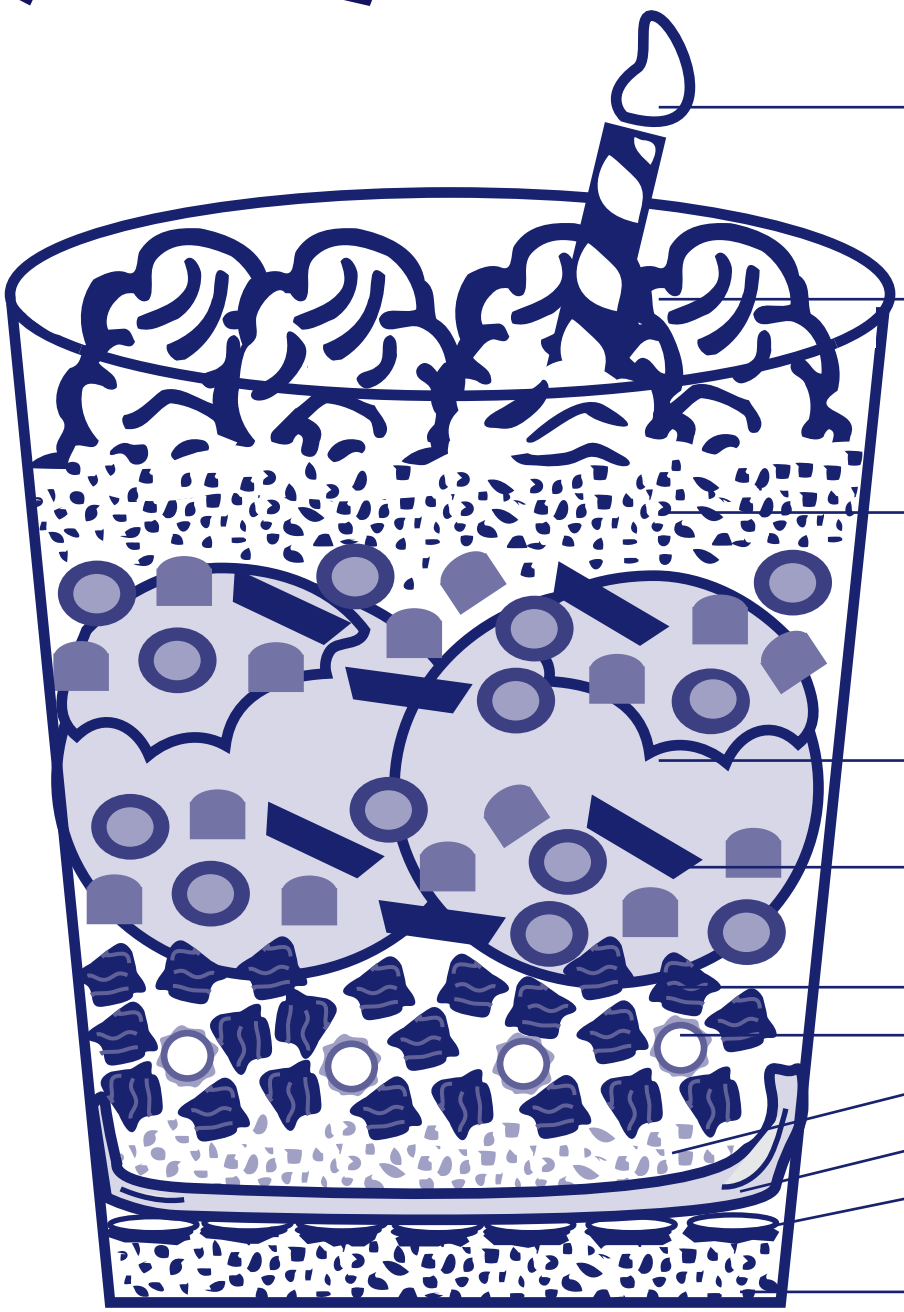
Assessment

1. After enjoying the luscious layered landfill as a snack, ask the students if they remember the purpose of all the different parts, such as the fruit roll-up, the licorice, the cookies, and your candle.

Enrichment

1. Contact a landfill in your community and take a tour. Ask to hear about all the different parts of the landfill. If your landfill recovers methane for energy, ask for a tour of the plant.
2. Have students conduct a survey of friends and family asking them where their garbage goes. Have them record peoples' responses and determine whether they are well informed. In class, discuss the survey results.

Anatomy of a Landfill



Methane gas recovery system (candle): recovers gas for energy from decomposing garbage

Landfill cap (whipped cream): prevents odor, insect, and rodent problems

Soil layer (cookie pieces): used to cover daily garbage

Leachate (ice cream): natural byproduct of decomposing garbage

Garbage (candies): added daily from communities

Pebble layer (raisins): prevents liquid from seeping out

Leachate pipe (licorice stick): collects leachate

Sand layer (graham crackers): prevents liquid from seeping out

Plastic liner (fruit rollup): prevents leachate from escaping into the ground

Clay layer (cookie pieces): absorbs any leachate (or liquid) that escapes the plastic liner

Soil layer (crushed cookies): lines the bottom of the landfill

Student Handout

science

social studies

A Landfill Is No Dump!

Objective

To teach students where garbage goes and explain the difference between unlined trash "dumps" of the past and today's specially designed landfills.

Activity Description

Students will construct models of an old-fashioned "dump" and a modern landfill in class and observe their differences.

Materials Needed

- Two plastic colanders (9 inches wide by 4 inches deep)
- Two cake pans (9 inches)
- One 10-pound bag of garden soil
- One 32-ounce bottle of distilled water
- Small pieces of typical home-generated garbage (see below)
- One package of modeling clay
- One roll of colored (red) crepe paper
- Clear tape
- One measuring cup
- One pair of scissors
- One package or roll of litmus (pH) paper
- One copy of the *Landfill Log* worksheet for each student

Key Vocabulary Words

Organic
Municipal solid waste
Landfill
Leachate
Groundwater
Turbidity
pH

Duration

Landfill creation: 1 hour
Observation over 4 weeks: 15 to 20 minutes each week

Skills Used

Observation/classification
Problem solving

Activity

Step 1: Photocopy and distribute *Landfill Log* worksheets to each student. Bring in some small pieces of garbage from your home, such as potato peels, apple cores, newspaper, and plastic yogurt containers. Introduce the following topics or concepts (refer to the Teacher Fact Sheets titled *Solid Waste* on page 47 and *Landfills* on page 165 for background information):

- Trash generation and disposal.
- How trash has been disposed of in the past and how it is disposed of now.
- Explain, in general terms, how a landfill works.
- Define each of the key vocabulary words used in the lesson.

Ask students to write a haiku or sonnet about where their garbage goes.

Step 2: Begin the exercise by asking a student volunteer to line one colander with flattened modeling clay, patting it out flat like a pie crust. Explain that this represents the liner of a sanitary, modern landfill. Do not line the second colander. Note that it represents an old-fashioned, unsanitary dump.

Step 3: Have several students cut the different garbage items you brought in from home into small pieces, about 2 inches square.

Step 4: Have a few student volunteers place this trash and the garden soil in the colanders in alternate layers until the colanders are full. For each layer, add 1 inch of garbage covered by 1/4 inch of dirt. Add several strips of red crepe paper as one layer toward the bottom of the colanders and cover them with more dirt. (The red crepe paper will emphasize the seepage of water through the unlined dump.)

Step 5: Place cake pans under the colanders to collect the seepage.

Step 6: Have students simulate "rain" on the "landfills" by pouring 1 cup of water onto each colander twice a week for 4 weeks. Ask students to observe the changes that take place. Pay particular attention to any water that collects in the cake pans. The unlined colander's seepage should be observable and colored by the crepe paper. The lined colander should not leak.

Step 7: After every "rain" session, have the students use a measuring cup to measure the water that leaked out of the unlined colander. Have students observe and record the water's color and turbidity. Ask for volunteers to test the pH of the collected water with litmus paper. Ask students to record results and observations in their *Landfill Logs*. For comparison purposes, have students test and record the pH of the distilled water.

Step 8: Next, have student volunteers put the "dirty" water from the unlined colander in a plastic cup. Fill another plastic cup with distilled water.

Step 9: Ask students to pretend that the dirty water or "leachate" had escaped an unlined landfill and reached surrounding plants and animals. Ask them what effect they think the liquid would have on animal or plant life. Ask students to predict how a piece of celery (representing a plant) would react to the leachate or "dirty" water.

Step 10: Insert two pieces of celery—one into the leachate cup and one into the distilled water cup. Point out to students how the celery stalk absorbs all of the color from the crepe paper, or dirt and toxins, of the leachate. Have students record observations about the process and the differences between the two pieces of celery.

Assessment

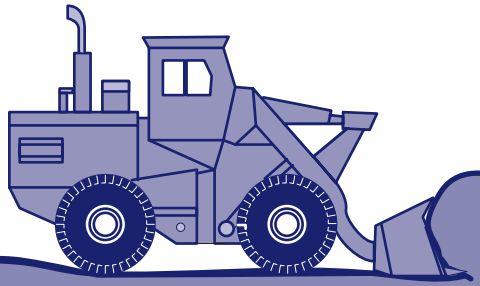
1. Ask students to explain the differences between the mini-landfills.
2. Ask students to refer to their *Landfill Logs*. How did the color, turbidity, and pH of the leachate and the distilled water differ? Why?
3. Have students describe how an unlined landfill or "dump" can pollute ground water and surrounding soil.
4. Ask students to decide which landfill is better for the environment and why. Which kind of disposal facility would they rather have in their neighborhood?
5. Ask students to define the key vocabulary words of this lesson. Conduct a spelling bee using these words.

Enrichment

1. Take a field trip to a local landfill. Have kids tour the facility and learn firsthand how it operates. When you return, have students write a paragraph about their visit, including five new facts about landfills that they learned.
2. Contact your state solid waste or environmental agency to find out how many landfills are in your state. If one is located near you, ask how many tons of trash it accepts per day or per year and its lifetime maximum capacity. Have students use data obtained from the agency to calculate how quickly the landfill is filling up. Have students make graphs to show how much longer it can accept garbage at its current rate.

Landfill Log

Name: _____



Observations

Date	Amount of Leachate	pH of Leachate	pH of Distilled Water	Color of Leachate	Turbidity of Leachate	Celery in Leachate (one-time observation)	Celery in Distilled Water (one-time observation)
Week 1 Rain 1 Rain 2	½ cup	9	7	brown and red	murky and filled with particles		
Week 2 Rain 1 Rain 2							
Week 3 Rain 1 Rain 2							
Week 4 Rain 1 Rain 2							

science

language arts

Energy Expedition

Objective

To introduce students to the concept of energy and teach them about its connection to trash.

Activity Description

Students will complete the *Energy Expedition* worksheet individually or in pairs.

Materials Needed

- One photocopy of the *Energy Expedition* worksheet per student
- One pencil or pen per student

Key Vocabulary Words

Potential	Combustion
Fossil	Methane
Coal	Solar
Gas	Water
Trash	Oil

Duration

1 hour

Skills Used

Reading
Problem solving

Activity

Step 1: Distribute one copy of the *Energy Expedition* worksheet to each student. Introduce the concept of energy—what it is, what it's used for, and where it comes from. Next, discuss the link between energy and trash; explain how we can capture methane gas from landfills to burn as energy for the community or local businesses. In addition, discuss how we can capture energy by burning our trash in combustion facilities. Refer to the Teacher Fact Sheets titled *Landfills* on page 165 and *Combustion* on page 169 for background information.

Step 2: Depending on student ability levels, use the Teacher Answer Key to go over the key vocabulary of this activity in advance, discussing each word and its meaning with the class. This will help them correctly complete the written activity later.

Step 3: Direct students to complete the *Energy Expedition* worksheet, working either individually or in pairs.

Journal Activity

Have students keep an energy diary for one week. Ask them to record every time they use energy in a day (for example, turning on lights, using a car or bus). Where could they have saved energy (for example, riding a bike instead of using a car)?

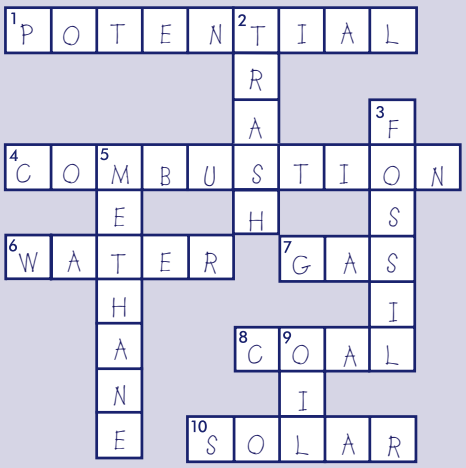
Assessment

1. Collect the *Energy Expedition* worksheets and assess students' work.
2. Ask students to list at least four different sources of energy.

Enrichment

1. Visit a waste-to-energy facility as a field trip. Have students write summaries that explain how the facility works.
2. Divide the class into groups and assign them each an energy concept (such as those introduced in the *Energy Expedition* worksheet.) Ask each group to conduct research on their topic and prepare a presentation to teach the class about their findings.
3. Conduct a spelling bee using the energy words featured on the *Energy Expedition* worksheet.

Crossword Puzzle Key

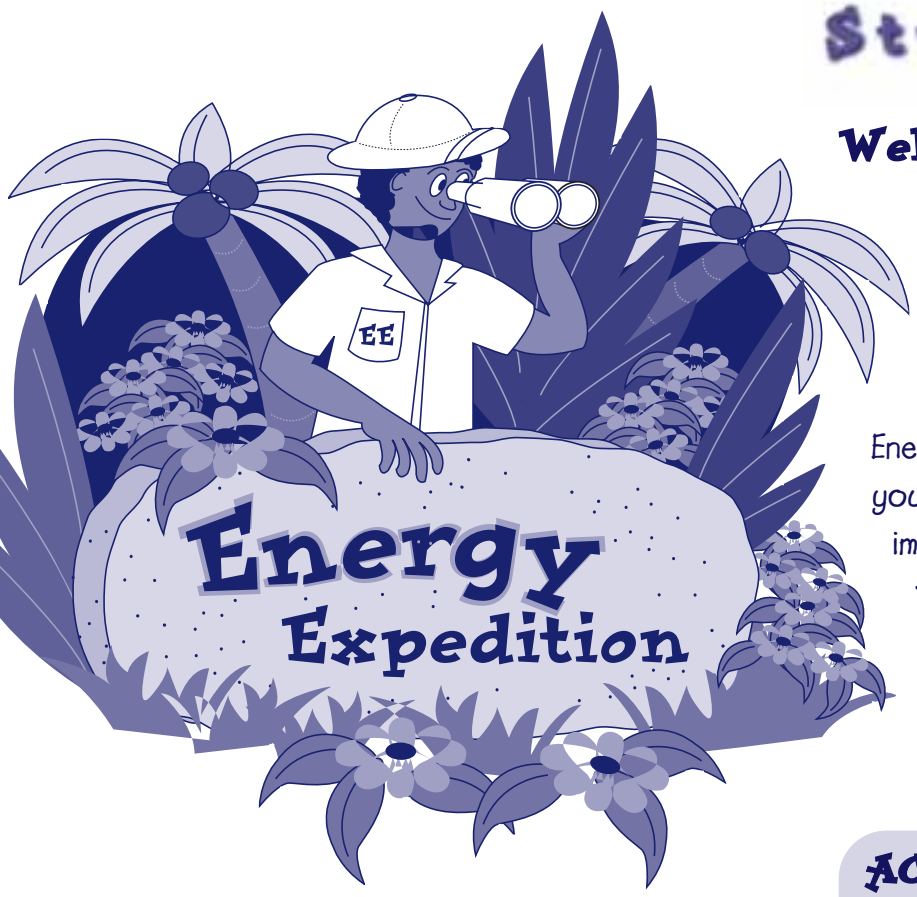


ACROSS

1. A type of energy. The word describes something that's "possible, but not certain." potential
4. The process of burning a material or substance. It's another word for "incineration," and its letters might "bust!" combustion
6. A liquid that we can control and direct to generate energy. You might drink it or swim in it. water
7. A substance that is neither liquid, nor solid, but can be removed from the Earth and used to generate power. gas
8. A hard, black substance that we burn for fuel. coal
10. A word describing energy from the sun. It rhymes with "polar." solar

DOWN

2. It's another word for unwanted material that you throw out into a container every day. You might set it out on the curb or throw it in a dumpster. trash
3. The hard rock-like remains of prehistoric animal and plant life, such as dinosaurs, which we sometimes discover in the Earth's crust. fossil
5. A natural gas that is generated by garbage decomposing in a landfill. Live animals can produce this gas as well...such as a cow burping! The word ends in "ane," but it's not "propane." methane
9. The liquid that we pump from the Earth's surface to burn for fuel. This work also applies to a product we often use in cooking. oil

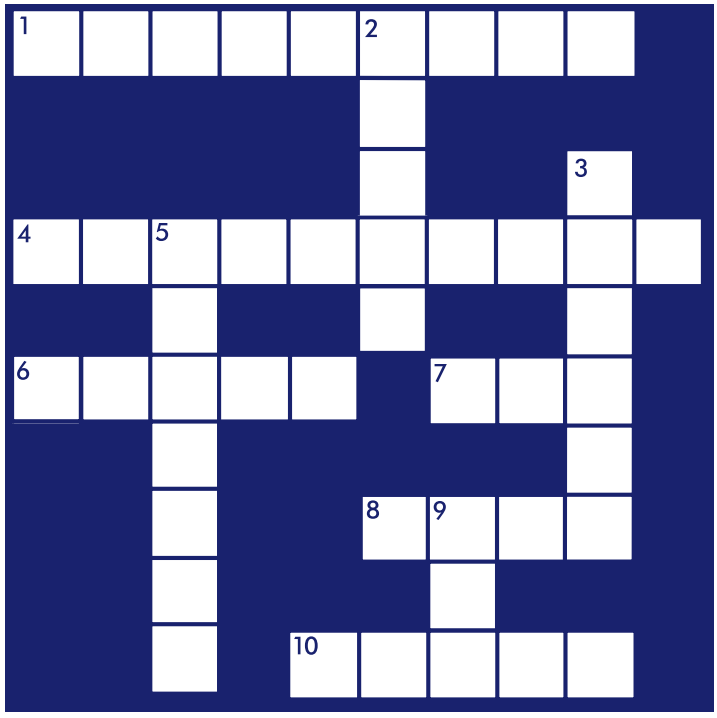


Welcome Energy Explorer!

You're about to set out on a mission to investigate ENERGY, including its uses, sources, and connection to our trash. If you accomplish your mission, you'll be promoted to an Energy Expert—and you'll be able to help your family and friends understand how important energy is to them and their way of life. This mission is not easy, however, and it will take all of your concentration and effort to crack the energy mystery. Good luck!

Name:_____

Directions: Your first task is to complete the Energy Crossword Puzzle below using the clues provided. Once you have filled in the crossword puzzle, you'll have a list of ten important energy vocabulary words.



ACROSS

1. A type of energy. The word describes something that's "possible, but not certain." _____

4. The process of burning a material or substance. It's another word for "incineration," and its letters might "bust!" _____

6. A liquid that we can control and direct to generate energy. You might drink it or swim in it. _____

7. A substance that is neither liquid, nor solid, but can be removed from the Earth and used to generate power. _____

8. A hard, black substance that we burn for fuel. _____

10. A word describing energy from the sun. It rhymes with "polar." _____

DOWN

2. It's another word for unwanted material that you throw out into a container every day. You might set it out on the curb or throw it in a dumpster. _____

3. The hard rock-like remains of prehistoric animal and plant life, such as dinosaurs, which we sometimes discover in the Earth's crust. _____

5. A natural gas that is generated by garbage decomposing in a landfill. Live animals can produce this gas as well...such as a cow burping! The word ends in "ane," but it's not "propane." _____

9. The liquid that we pump from the Earth's surface to burn for fuel. This word also applies to a product we often use in cooking. _____

Energy Story

Directions: Great job! You've now learned ten important energy vocabulary words! Read the story below to learn more about energy and become an Energy Expert. You must determine which of your ten vocabulary words goes in each blank. Remember, some words will be used more than once. After you have filled in all of the blanks, you'll have successfully completed your energy mission!

What is ENERGY?

Energy is one of the most important parts of our world—it makes things happen. Energy means the "ability to do work." Did you know that you use energy every day? Every time you flip a light switch on; use hot water; or ride in a car, bus, train, or plane, you are using energy. Each time you watch TV or use a computer, you are using energy. All of the clothes that you wear, toys you play with, and food you eat are products made from processes that require energy.

There are two different types of energy:

- Energy that is stored is called _____ energy.
- Energy that is moving is called kinetic energy.

Let your pencil rest on your desk. Right now, if it's not moving, your pencil has_____**(same as previous blank)** energy. Now, tap it lightly so that it rolls across your desk. Since it's moving, the pencil now has kinetic energy.

Where does ENERGY come from?

There are many different sources of energy on Earth and there are many different ways that we can tap into those sources and make the energy work for us—creating power, electricity, and heat.

One source of energy upon which we rely heavily are_____ fuels. How were these fuels formed? Millions of years ago, ancient plants absorbed the energy from the sun and converted it into more plants. Ancient animals, like dinosaurs, ate the plants and converted the plant's energy into body mass. When the animals and dinosaurs died, their remains collected in the ground, and, over millions of years, decomposed into a source of fuel.

What are some_____ **(same as previous blank)** fuels? Coal, oil, and natural gas are three important fuels that are derived from the Earth and the stored energy of organic remains.

_____ started out as a spongy, brown material called "peat," which consists of the decomposed organic matter of ancient animals and plants. Geologic forces buried the peat deep under the Earth's surface, where it was further packed down by heat and pressure. The compressed peat was eventually converted to_____**(same as previous blank)**.
We burn_____ **(same as previous blank)** to heat our homes and run electrical machinery. About 20 percent of the energy we use comes from _____**(same as previous blank)**.

_____ is formed deep within the Earth's surface in rocks that are fine-grained and rich in the organic remains of once-living animals. The oldest_____**(same as previous blank)** -bearing rocks date back more than 600 million years. _____ **(same as previous blank)** is burned to fuel vehicles and heat homes. About 45 percent of the energy we use comes from _____**(same as previous blank)**.

Natural _____ is a colorless, odorless fuel produced by drilling into the Earth's crust where it was trapped hundreds of thousands of years ago. Once it is brought to the surface, it is refined and purified to remove water, other gases, and sand. Next, it's transported through large metal pipelines that span the continent. Natural _____ **(same as previous blank)** is used for heating, cooling, and the production of electricity.

How is ENERGY connected to trash?

While these sources of energy continue to serve us well, they are known as nonrenewable resources that will eventually be used up. Once we use all of our supplies, we will have to depend on new sources of energy. We're already looking for new energy sources so that we can conserve those that come from within the Earth. That's where_____ comes in. Did you know that you can get energy from _____**(same as previous blank)**? There are two ways that we can use our_____ **(same as previous blank)** to make energy.

In one method,_____**(same as previous blank)** is taken to a waste-to-energy facility. These facilities burn the _____ **(same as previous blank)** during a process called_____. This process generates heat that can be converted to fuel and electricity. Waste-to-energy facilities take a large amount of trash and make it smaller by burning it. This reduces the amount of trash that piles up in our landfills, which is better for the environment.

A second way for us to use trash for energy involves the garbage that we dispose of in landfills. As this trash decomposes, it produces _____ gas. Too often, this valuable source of energy is not used. Now, however, over 150 landfills in the United States are using the gas, captured by a special pipe system set up in the landfill, to generate electricity; provide fuel for factories, schools, and other facilities; and to produce natural gas for general distribution.

Are there any other sources of ENERGY?

In addition to using the energy we generate from our garbage, there are other ways we can harness the renewable energy sources that surround us. Here are two other important energy sources that we are just beginning to use in place of fossil fuels.

The light that comes to the Earth from the sun is pure energy. Nearly all other sources of energy originally got their energy from the sun. Organic matter, like plants, convert _____ energy into leaves, flowers, and fruits. We can also use energy from the sun to heat our homes and buildings with special _____ **(same as previous blank)** panels that capture and convert the light into energy.

Hydroelectric power is generated by harnessing _____. When _____ **(same as previous blank)** falls or runs downhill, it can be used to run turbines or large water wheels at mills and factories, which generate electricity.

Now you understand how our trash can help us generate power and electricity. In addition, you've learned all about our use of energy on this planet and the many different sources we can turn to for energy use in the future.

The Great Disposal Debate

Objective

To teach students about some of the environmental, social, and economic issues surrounding modern landfills, incinerators, and other forms of waste management.

Activity Description

Students will research and debate the pros and cons of using landfills for waste disposal and energy generation, and then compare with other forms of waste disposal and energy generation.

Materials Needed

- Index or note cards for each student
- Internet, library, encyclopedia, or other access to research resources
- Background information from Teacher Fact Sheets and other resources listed below

Key Vocabulary Words

Decomposition
Greenhouse gases
Ground water
Incinerator
Landfill
Leachate
Methane

Duration

Day 1: 1 hour
Day 2: 1 hour

Skills Used

Research
Reading
Problem solving
Communication

Activity

Day 1

Step 1: Introduce the concept of the modern landfill and explain some of the advantages and disadvantages to this form of waste disposal. (Refer to the Teacher Fact Sheets titled *Landfills* on page 165, *Combustion* on page 169, *Solid Waste* on page 47, and *Hazardous Waste* on page 51 for background information. Teachers may also choose to use the History Channel's video, *Modern Marvels: Garbage*, which provides information on sanitary landfills and the history of garbage; contact (800) 941-4007 or <www.AandE.com> for more information.)

Step 2: Once the students understand the above concepts, divide the class into two groups: Pros and Cons.

Step 3: As a homework assignment or an in-class teacher-led group activity, have students conduct research and come up with at least three points or arguments defending their side of the debate (i.e., pros or cons associated with landfills). Encourage students to use the school library, Internet, or other resources, such as contacting the regional solid waste agency or local recycling coordinator. Teachers may also choose to provide students with Enviroscapes' Landfill Model, which compares old garbage dumps to modern sanitary landfills. For more information, email <info@enviroscapes.com> or visit <www.enviroscapes.com>.

Journal Activity

Ask students to think about the advantages and disadvantages associated with landfills. Which one issue is most important to them? Why?

Day 2

Step 1: On day two, have the two sides regroup to discuss what they discovered through their research. Give each group 15 to 20 minutes to work together and prepare their side of the debate on either the pros or cons of landfills. During that time, ask the students to combine their note cards and assemble them in order of importance for easy reference during the debate. Instruct students to pick four classmates to represent the group as the debaters.

Step 2: Explain that each team will get 5 minutes to present their side of the debate. During that time, any of the four designated debaters for that team can speak, but they must take turns. After one side presents, the other team has 5 minutes to present their points.

Step 3: After the formal debate is over, allow each team to respond to one or more of the issues raised by the other group. The teacher may choose to serve as a moderator during this question and answer session.

Step 4: At the end of the debate ask the students if they were persuaded by either side and why.

Assessment

1. Ask the students to discuss/explain whether or not they would want a landfill in their community. Why or why not?
2. How does the debate change if the landfill is used for electricity generation? Does this benefit outweigh some of the negatives? Does this change the students' opinions/ perceptions of landfills?

Enrichment

1. Have students create a survey and conduct interviews with family members or friends to determine how other people feel about landfills. Compile, analyze, and discuss the results of the surveys in class. Make graphs or charts based on these results.
2. Have each student group research how garbage was disposed of in Medieval times, the 1800s, and early 1900s. How does this compare to today's disposal methods? Have one group of students research how garbage is disposed of today in countries other than the United States. Ask the students how they think garbage may be handled in the future.
3. Take a field trip to a local landfill to tour the facility and learn how it works. When you return, have the students write a paragraph on their visit, including five new facts.
4. Explore the issues of greenhouse gases and global climate change in more depth. Use the example of capturing methane from landfills for energy as one way to help reduce greenhouse gas emissions. Ask the students to think of other ways we might reduce greenhouse gases. Examples include using less electricity, creating less garbage (see section on *Source Reduction*), improving technologies to cleanup power plants emissions, and planting trees. (See EPA's Web site on methane, <www.epa.gov/methane/index.html>, and global warming, <www.epa.gov/globalwarming>, for reference information.)

A Look at Landfills

Pros

- Gives us somewhere to put our solid waste.
- Is more protective than dumps of the past.
- Waste decomposition at a landfill generates methane—a potent greenhouse gas that can be captured and used for energy.
- Converting methane to energy can help reduce greenhouse gas emissions—directly, by capturing methane from the landfill, and indirectly by serving as an alternative energy to fossil fuels.
- Can be properly capped and use for park land, playgrounds, or other nonresidential purposes.
- Can provide a source of jobs and income for a town or state that is willing to accept solid waste from other cities, towns, or states for a fee ("host fees").
- Using a local or nearby landfill can cut down on fuel emissions from trucks and boats carrying waste to faraway areas.

Cons

- Can cause noise and traffic with trucks driving to and from the landfill.
- Must be designed and constructed to prevent contamination of ground water, surface water, and soil.
- Can lead to bad smelling (rotten egg) or unhealthy air.
- If not properly capped and managed, can attract birds and pests.
- May lower the property values of the surrounding area.
- Shipping waste to a landfill in another state or county may lead to dust problems or blowing trash if not covered properly.
- Loose garbage can blow around if landfill is not properly capped and managed.

Greenhouse Gases Be Gone

Objective

Educate students about the differences in greenhouse gas emissions as they relate to different forms of waste and waste disposal methods.

Activity Description

Students will research various forms of waste disposal and use EPA's Waste Reduction Model (WARM) to calculate greenhouse gas emissions associated with waste and waste disposal methods.

Materials Needed

- EPA's Waste Reduction Model (WARM) (available at EPA's Global Warming Web site: http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ActionsWasteWARM.html
- Computer (with Internet access or Microsoft Excel)
- EPA's Web site on Climate Change and Waste: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWaste.html
- Pencils
- *Weekly Waste Generation Tracking Sheets*
- Library

Key Vocabulary Words

Carbon dioxide
Emissions
Global climate change
Greenhouse gases
Recycling
Solid Waste
Source reduction

Duration

3 hours (in class)

Skills Used

Computation
Observation/Classification
Research
Reading
Problem Solving

Activity

Part 1

Step 1: Review the various methods of handling waste (including source reduction, recycling, landfilling, composting, and incinerating) using the Teacher Fact Sheets titled *Source Reduction* on page 79, *Recycling* on page 101, *Buying Recycled* on page 107, *Composting* on page 141, *Landfills* on page 165, and *Combustion* on page 169. Define greenhouse gases and explain how the various factors of waste disposal (type of waste, type of disposal, transportation) affect greenhouse gas emissions and thus global climate change. (For information on the connection between waste and climate change see EPA's Web site at <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWaste.html>.)

Step 2: Hand each student a *Weekly Waste Generation Tracking Sheet* and ask them to fill it out every day for one week. Have the students take the sheet home every evening to record their waste generation at home. Remind them to include the materials they use both in

school and home, such as drink cans and cartons, lunch bags, and looseleaf and printer paper.

Step 3: During this same week, have students research how each type of waste (e.g., aluminum, food scraps, newspaper) is normally disposed of, particularly in their town or county. (Tip: You may want to assign one specific waste to individual groups of students.) Teachers will use this information to enter data into the baseline scenario of EPA's Waste Reduction Model (WARM).

Two Methods for Gathering Information

Teachers may choose between two methods for gathering the necessary information to input into WARM (Part 1, Step 2):

- ***Simpler***—Students will track the amount of each material type they dispose of each day. The teacher will use this information (as directed Part 2, Step 3) as baseline data and then try different combinations of alternative waste disposal methods in WARM and discuss the results with the class.
- ***Complex***—Students will track both the amount of each material type they dispose of each day and the method of disposal (throw out, recycle, compost). The teacher will use this information as directed Part 2, Step 3 to complete the WARM spreadsheets.

Part 2

Step 1: The following week collect the *Weekly Waste Generation Tracking Sheets* from the students and tally the results into one combined tracking sheet. This represents the weekly waste generation for the class. In order for the WARM tool to give meaningful results, however, the class will need to take the weekly waste generation information and project the total waste generation (by commodity) for the class for the year. (Depending on the size of the class, teachers may need to take this one step further and project the yearly waste generation for the school.) Convert this number into tons for input into WARM.

Step 2: Review the discussion on greenhouse gases and their relationship to waste and waste disposal (as described in Part 1: Step 1).

Step 3: Access EPA's WARM calculator at <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html>. Explain that this tool is often used by solid waste planners and organizations to track, report, and estimate the effects of various waste disposal methods on greenhouse gas emissions. The model calculates greenhouse gas emissions for baseline and alternative means of waste management. Discuss how people can use models to predict possible future scenarios, such as the effect of certain activities on air or water pollution, or a new street layout on rush hour traffic conditions. Enter the information for baseline data as gathered by the class. (Teachers can enter data into the online spreadsheets and print out the results but cannot save them. Therefore, teachers may choose to download the Microsoft Excel file, which can be saved.)

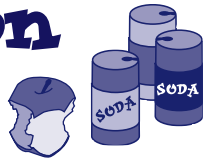
Step 4: Working with the students, enter data into the alternative management scenario and complete the WARM spreadsheet. Review and discuss the results of various waste management practices on greenhouse gas emissions. Ask the class to observe whether the alternative management scenario reduced the amount of emissions. Why or why not? Try incorporating different waste management practices to view the effects on emissions and discuss the results with the class.

1. Ask the students what they learned from using the tool and how this might be applicable to the real world. How might communities use tools such as WARM to help manage their waste and minimize their impacts on global climate change?

1. Contact a local solid waste planner or organization and ask them to fill out WARM. Had they heard of this tool before? How did their baseline and results compare with the class?
2. How do greenhouse gas reductions achieved with alternative waste management methods relate to real life? Equivalency calculators convert emissions or energy use reductions into more understandable terms, such as number of cars removed from the road or acres of trees planted. Use the information generated by the class and WARM to complete the *Greenhouse Gas Equivalencies Calculator* available at <www.usctcgateway.net/tool/> or other tools available at <http://yosemite.epa.gov/OAR/globalwarming.nsf/content/ActionsWasteTools.html>. Discuss the results.

Student Handout

Weekly Waste Generation Tracking sheet



Name: _____ Enter the amount of each item that you discard each day.

Material	Day 1	Day 2	Day 3	Day 4
Aluminum Cans				
Steel Cans				
Glass				
HDPE (plastic)				
LDPE (plastic)				
PET (plastic)				
Mixed Plastics				
White (printer) Paper				
Textbooks				
Magazines				
Newspaper				
Food Scraps				
Grass				
Leaves				
Yard Trimmings				
Mixed Paper (general)				
Mixed Metals				
Mixed Recyclables				

Name: _____ Enter the amount of each item that you discard each day.

Material	Day 5	Day 6	Day 7	Total
Aluminum Cans				
Steel Cans				
Glass				
HDPE (plastic)				
LDPE (plastic)				
PET (plastic)				
Mixed Plastics				
White (printer) Paper				
Textbooks				
Magazines				
Newspaper				
Food Scraps				
Grass				
Leaves				
Yard Trimmings				
Mixed Paper (general)				
Mixed Metals				
Mixed Recyclables				